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Predicting High-Power Performance in Professional Cyclists

Dajo Sanders, Mathieu Heijboer, Ibrahim Akubat, Kenneth Meijer, and Matthijs K. Hesselink

Purpose: To assess if short-duration (5 to ~300 s) high-power performance can accurately be predicted using the anaerobic power reserve (APR) model in professional cyclists. **Methods:** Data from 4 professional cyclists from a World Tour cycling team were used. Using the maximal aerobic power, sprint peak power output, and an exponential constant describing the decrement in power over time, a power-duration relationship was established for each participant. To test the predictive accuracy of the model, several all-out field trials of different durations were performed by each cyclist. The power output achieved during the all-out trials was compared with the predicted power output by the APR model. **Results:** The power output predicted by the model showed very large to nearly perfect correlations to the actual power output obtained during the all-out trials for each cyclist ($r = .88 \pm .21$, $.92 \pm .17$, $.95 \pm .13$, and $.97 \pm .09$). Power output during the all-out trials remained within an average of 6.6% (53 W) of the predicted power output by the model. **Conclusions:** This preliminary pilot study presents 4 case studies on the applicability of the APR model in professional cyclists using a field-based approach. The decrement in all-out performance during high-intensity exercise seems to conform to a general relationship with a single exponential-decay model describing the decrement in power vs increasing duration. These results are in line with previous studies using the APR model to predict performance during brief all-out trials. Future research should evaluate the APR model with a larger sample size of elite cyclists.

Keywords: training, anaerobic power, aerobic power, cycling

In cycling, mainly an aerobic marker such as power output at maximal oxygen uptake ($\text{VO}_{2\text{max}}$) or functional threshold power is used as a reference to set intensity for high-intensity interval training (HIT).¹ In practice however, 2 cyclists with similar power output at $\text{VO}_{2\text{max}}$ can have significantly different sprint peak power outputs. Therefore, if the intensity of a HIT session is exclusively based on a percentage of power output at $\text{VO}_{2\text{max}}$ (eg, intervals at 130% of power output at $\text{VO}_{2\text{max}}$), the athlete with the higher sprint peak power output has to work at a lower percentage of his or her maximal anaerobic capacity, which results in a different physiological demand and exercise tolerance.² Therefore, exercise intensity of supramaximal HIT should be individualized based on a combination of aerobic and anaerobic capacity to have the same training impact among different individuals.²

The anaerobic power reserve (APR) is defined as the difference between maximal sprint peak power output and power output at $\text{VO}_{2\text{max}}$.³ Studies have used the APR range to set the minimal and maximal values of a high-power duration curve. With this power-duration curve, the performance of all-out efforts lasting from a few seconds to a few minutes can be predicted.³⁻⁶ This individual power-duration curve obtained by the APR model could be useful in prescribing exercise intensity and work durations for (supramaximal) HIT.² The principle of this model is based on the assumption that the exponential decrement in high-power performance in relation to duration is the same for different athletes in relation to their APR.^{3,5} However, it remains questionable if the APR is applicable

in high-level (endurance) athletes such as professional cyclists.⁷ Furthermore, evidence of the applicability of a field-based approach to the APR concept could be valuable for coaches and practitioners. This report presents 4 case studies assessing the applicability of the APR model in professional cyclists using field-based tests.

Methods

Subjects

Four high-level endurance athletes from a Union Cycliste Internationale (UCI) World Tour professional road cycling team participated in this investigation (mean \pm SD age 30 ± 5 y, height 1.83 ± 0.04 m, body mass 74.9 ± 4.3 kg). Data were collected from routine exercise testing and training of the cyclists. Permission was obtained from the team and cyclists for the use of this data.

Testing

Power at maximal aerobic capacity was determined using an incremental field test protocol. Each cyclist performed 6 stages consisting of 6 minutes each on uphill terrain (mean gradient of 4.8%). Based on preseason laboratory testing, individual guidelines for the power output for each stage were provided for the riders before the field test (average increment of 31 ± 4 W/interval). After the 6-minute interval, the riders had 6 to 10 minutes of active recovery ($<55\%$ of power output at anaerobic threshold) before starting the next interval. The last effort was a 6-minute all-out performance; the mean output during these 6 minutes was used as the maximal aerobic capacity.^{2,8} Power output was measured using a mobile ergometer system (Pioneer Power Meter, Kawasaki, Kanagawa, Japan). Although no pulmonary gas exchange measures were taken during this test, power output during the last block of an incremental test is largely correlated with maximal aerobic capacity.² Sprint peak power output was defined as the maximal peak 1-second power output the cyclists could achieve

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during all-out standing sprints in the field. Before the incremental field test, 3 maximal sprint trials of 10 seconds were performed. The sprints were performed as “flying sprints” with the cyclist already riding at 30 to 35 km/h. The cyclists performed the sprints on their own bike with a cadence preferred by the cyclists (99 ± 7 rpm).

Anaerobic Power Reserve

Based on the anaerobic reserve model, a power-duration relationship was established individually for each subject. This relationship was set using the following formula³:

$$PO_t = PO_{\text{aer}} + (PO_{\text{sp}} - PO_{\text{aer}}) \times e^{-(k \times t)}$$

where t is the duration of the all-out trial, PO_t is the power output maintained for that trial with a duration of t , PO_{aer} is the power output at maximal aerobic capacity, PO_{sp} is the sprint peak power output, e is the base of the natural logarithm, and k is the exponent that describes the decrement in power output over time. The exponential time constant describing the decrement in power over time used in this study is based on the previous established exponential power-duration curve fitted through data in recreationally active cyclists ($k = 0.026$).^{4,5}

All-Out Efforts

Several all-out efforts of different durations (5–120 s) were performed by each cyclist in a 4-week period. Every week, 3 all-out trials were incorporated into the training program. The trial was performed after a warm-up of 20 to 30 minutes (50–75% of power output at anaerobic threshold). The cyclists performed the efforts on their own bike with a cadence preferred by the cyclists (91 ± 6 rpm). Measured power outputs of the all-out trials were compared with the power output predicted by the APR model, providing individual correlation coefficients (r). Statistical interpretations and scale of magnitudes were based on the guidelines provides by Hopkins et al.⁹

Results

Power output achieved during the last 6-minute block of the incremental field test for the 4 subjects averaged 477 ± 24 W (range 444–501 W) and 6.4 ± 0.4 W/kg (Figure 1). The maximal power output achieved during the standing all-out sprints had an average value of 1317 ± 210 W (range 1036–1525 W) and 17.5 ± 2.3 W/kg (Figure 1).

Twenty-seven all-out trials were performed by the 4 subjects, varying from an all-out performance of 5 seconds up to 120 seconds in the 4-week period after the APR field tests. Even though substantial differences could be seen between subjects in absolute power outputs achieved during the all-out trials (Figure 1), when comparing the power output predicted by the APR model with the actual power output obtained during the all-out trials, very large to nearly perfect relationships were observed for the 4 subjects (Figure 2). Correlations coefficients ($\pm 90\%$ confidence limits⁹) observed were $r = .88 \pm .21$, $.92 \pm .17$, $.95 \pm .13$, and $.97 \pm .09$ for each subject, respectively. Power output during the all-out trials remained within an average of 6.6% (53 W) of the predicted power output by the model ($r = .96$) (Figure 3).

Discussion

This study presents 4 case studies of the applicability of the APR model in professional cyclists using a field-based approach. The APR model estimated a total of 27 trials from 4 professional

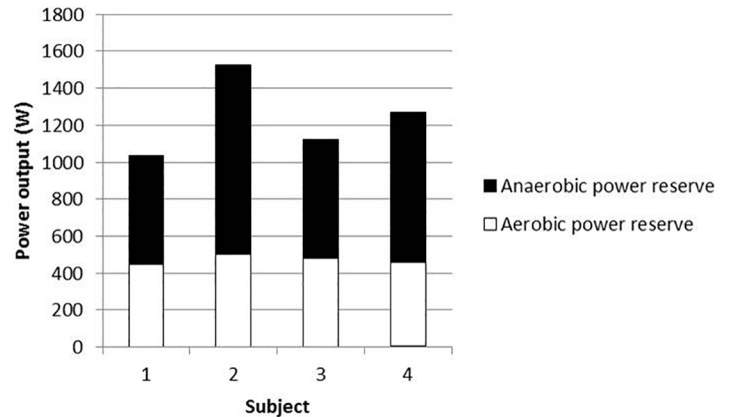


Figure 1 — Maximal sprint peak power output and maximal aerobic power output for each of the 4 subjects.

cyclists within an average of 6.6%. Results were lower compared with previously determined predictability for running (3.7% and 2.6%)^{4,6} and similar to predictability reported for high-power cycling performance (6.6%).³ It remains a challenge to do research in elite athletes with a large group of participants. However, even with a limited sample size, testing the applicability of these concepts in elite athletes could prove valuable for coaches and practitioners working with these athletes as they cannot rely solely on research with less trained subjects.

One aspect that needs to be taken into account is the individual differences in the applicability of the model. For participant 1, the model mostly overestimated the power output that was actually achieved during the all-out trials ($r = .88$), and in participant 4 the model mostly predicted lower power outputs than actually achieved during the trials ($r = .92$). Motivation, pacing, and post-race fatigue play important roles in the performance achieved during the all-out efforts, especially when taking into account the busy race schedule of these athletes.

A second important aspect is the testing methods to assess the anaerobic reserve range. The field tests used in this study are slightly different and less controlled compared with previous (laboratory) protocols used in Weyand et al.³ However, because of the intrusiveness of laboratory testing on the cyclists' training or competition program, field testing is more applied on a regular base in these athletes. Therefore, evidence of the applicability of a field-based approach to the APR concept is valuable for coaches and practitioners.

Practical Applications

By using 2 simple field tests to assess maximal aerobic power and maximal sprint peak power output, a power-duration curve from 5 to ~300 seconds can be established individually for each athlete. The power-duration curve predicted by the APR model can contribute to a more accurate and individualized training program.^{2,10} The application of different work to rest ratios in HIT and the impact on the type of adaptation has previously been discussed in research.² The APR model may help coaches set the correct intensities for different work to rest ratios to achieve the desired adaptation for cyclists with differing competition goals.

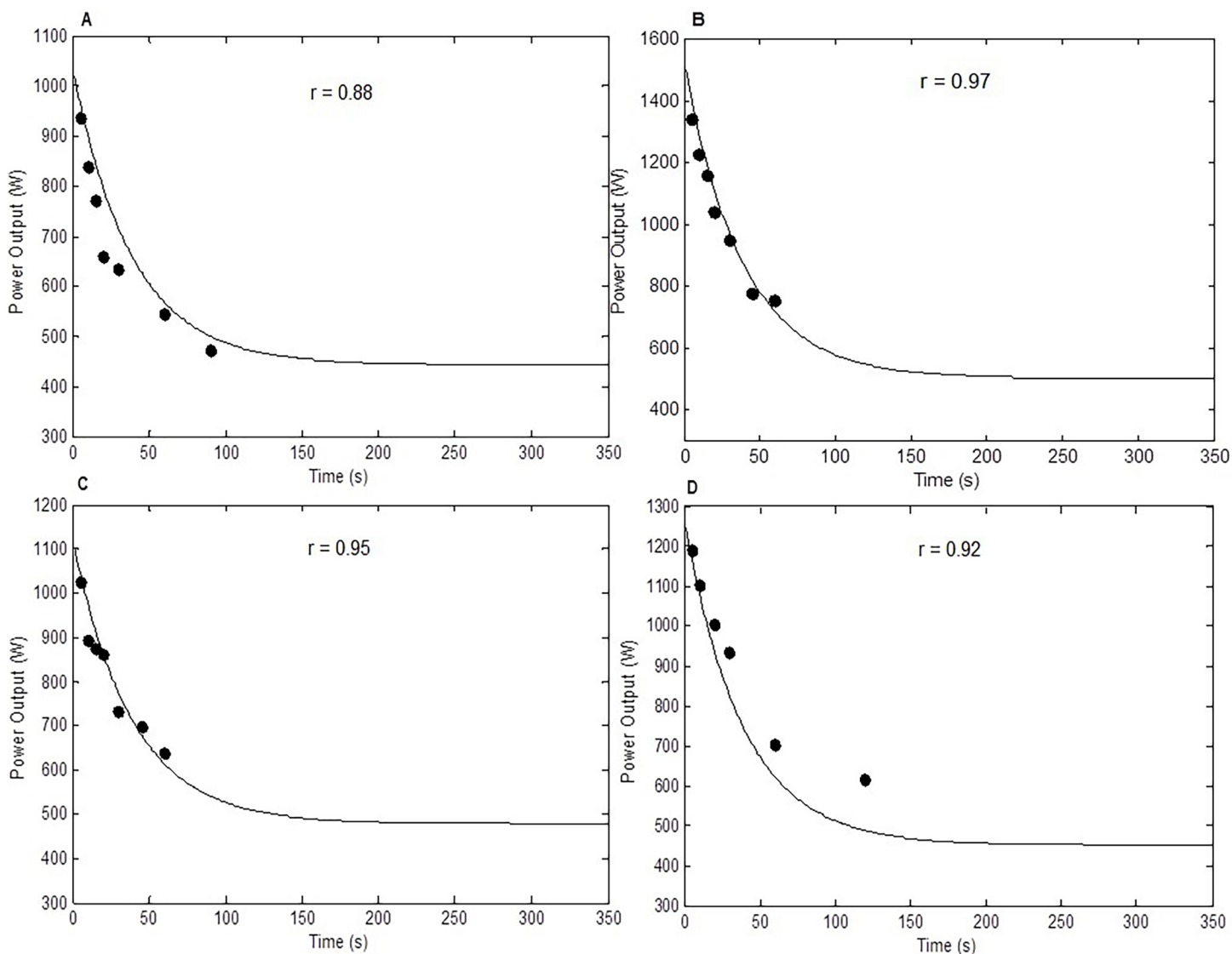


Figure 2 — Power duration curves for participant (A) 1, (B) 2, (C) 3, and (D) 4 when comparing predicted power outputs (line) with the all-out trials (black circles).

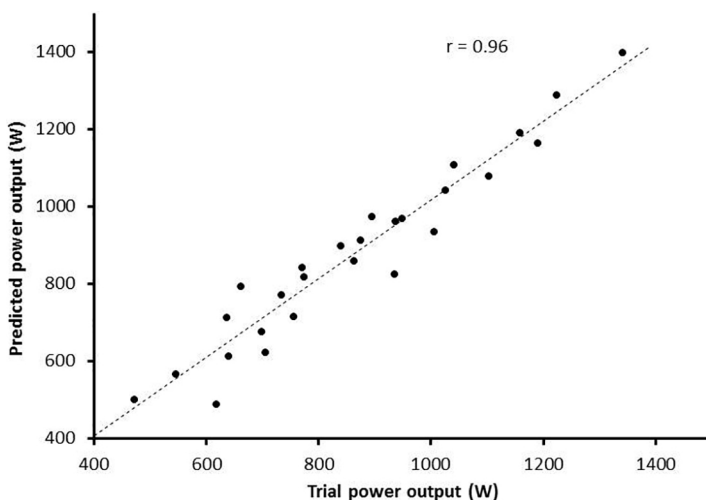


Figure 3 — Predicted power output by the anaerobic power reserve model versus actual power output achieved during all-out efforts.

Conclusions

This preliminary investigation shows 4 case studies on the applicability of the APR model in professional cyclists using a field-based approach. These results are in line with previous studies using an anaerobic power/speed model to predict performance during brief all-out trials.^{3,4,6} The determination of an APR range can contribute to the individualization of training intensity and demand during HIT sessions. Results should be considered promising with a view to verifying them with a larger pool of athletes.

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